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CANADIAN PATENT

LINER EXPANDER

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Granted to Pan American Petroleum Corporation, Tulsa, Oklahoma, U.S.A.

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No. OF CLAIMS

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LINER EXPANDER

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This invention relates to a constant force spring device, and more particularly, to a device for expanding a metallic liner wherein an expanding die is urged against the liner by a constant force spring device.

Heretofore, a method and apparatus have been developed for installing an expanded metallic liner in an oil well or other conduit. Typically, a corrugated steel liner is inserted in a conduit which is to be lined, the greatest peripheral dimension of the liner being slightly less than the inside diameter of the conduit. An expanding tool is passed through the liner placed in the conduit, and a first-stage expanding die causes a gross plastic deformation of the liner, which is expanded outwardly against the inside of the conduit. A second-stage die on the tool then provides an additional finer deformation of the liner to provide a smoother, more finished surface on the inside of the liner and to assure more complete contact between the conduit and the liner. In a typical design of this type expanding tool, the frictional drag of the first-stage die supplies the expanding force for the second-stage die, which expanding force is a direct function of the strength, or wall thickness, of the conduit in which the liner is being installed. For example, in lining oil well casing, heavy wall casing may cause a very high frictional force which results in excessive pressure being required to push the expander through the liner. The application of the great forces required may result in rupture of the casing or in breaking the installing tool. In instances where the internal diameter of the conduit is somewhat less than that anticipated, the resulting forces can cause the tool to become stuck in the casing, or otherwise cause damage to the casing and the tool. In other designs, such as where a cantilever spring arrangement is employed in connection with the secondstage die, various difficulties are encountered in obtaining a spring mechanism having the desired strength in combination with the other spring characteristics, and with the tool dragging against the inside wall of the conduit after being passed through the liner.

Since tools of the type mentioned above often are employed in wells deep in the ground, it is highly preferable that a tool be used which under no circumstances will become stuck in the well or cause damage to the well. Any such trouble occurring in a well can result in considerable loss in time and great expense in making repairs.

An object of the present invention is a device for applying a constant force to an expanding die or other similar apparatus so that a preselected maximum force is exerted against a work piece. Another object is an improved expanding tool for installing metallic liners in a conduit, which expanding tool can apply no greater than a predetermined force to the liner being installed in the conduit. Still another object of the invention is an economical and easily fabricated constant force spring device. A further object is a rugged, easy-to-operate expanding tool employing such a spring device. These and other objects of the invention will become apparent by reference to the following description of the invention.

In accordance with the present invention there is provided a constant force spring device which comprises a body member, an elongated column element adjacent said body member, bearing plate members contacting the two ends of said column at least one of said bearing plate members being longitudinally movable in respect of the other and stop means on said body member to limit the deflection of said column element to prevent permanent deformation of said column element upon the application of a compressive load thereto. In one embodiment of the invention, the foregoing constant force spring device is employed in a tool for expanding a metallic liner inside a conduit, said constant force spring device being positioned on said tool to urge an expanding die member against the liner being installed in the conduit by a substantially constant force.

My invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figures 1A, 1B and 1C, taken together, constitute a partial sectional view of a preferred embodiment of a liner expanding tool according to the present invention; and

Figure 2 is a sectional view of the apparatus of Figure 1A taken at line 2-2; and

Figure 3 is a typical plot of applied Load versus Deflection for the constant force spring device of the invention.

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Referring to the drawings, Figure 1A is the bottom portion of a liner expanding tool for use in installing a metallic liner in a well, while Figure 1B illustrates the middle section of such a tool and Figure 1C represents the upper section of the tool. The expanding tool 11 is attached to standard well tubing 12 by coupling 13 and, typically, may be lowered from the surface through a well casing (not shown) to a point in the casing at which it is desired to install a metallic liner. Before inserting the tool into the well, an elongated vertically corrugated liner 14 fabricated from mild steel, or other suitable malleable material, is placed on the tool. The corrugated liner is secured in position by contact at its upper end with a cylindrical shoulder member 16 and, at its lower end by contact with a first-stage expanding die 17 in the form of a truncated circular cone which serves as a firststage expanding die in the manner hereinafter described. The expanding die is fixedly attached to a centrally located, elongated cylindrical hollow shaft 18 which forms a portion of the body of the tool. As shown, the expanding die 17 is held in place between a lower shoulder 19 and collar 21 threaded onto the shaft. A plurality of movable arms 22, preferably provided with outwardly enlarged portions 23 near the top, are disposed in the form of a cylinder around shaft 18. The enlarged portions of the arms 23 upon being moved outwardly contact the liner to perform the final step of expanding the corrugated liner into a substantially cylindrical shape. The arm members 22 are pivotally attached to the shaft so as to be movable outwardly from the shaft by a tapered expanding member 24 slidably positioned on the shaft to serve as a second-stage expander. The surface of the member 24, as shown, moves upwardly along the shaft to engage with the arms and move them outwardly. Advantageously, the inside surfaces of the arms 22 and the outside surface of expanding member 24 form mating sections, typically octagonal in shape. The expansion of the arm members is controlled by the position of the member 24 which moves upwardly

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until it contacts shoulder 26 provided on the shaft. As member 24 moves in a downwardly direction arms 22 fold inwardly toward the shaft. The expanding arms 22 are held in place on the shaft by collar 27 and circular groove 28 provided on the shaft.

The expanding tool, comprising the first-stage die and the secondstage die is drawn through the liner to expand it in place in the casing. The
first-stage die provides a gross deformation of the liner so that it is
expanded outwardly against the wall of the casing. The second-stage die then
passes through the liner and performs the final expansion to smooth the inner
surface of the liner and to provide more even contact between the liner and
the wall of the casing and effect a fluid-tight seal.

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In operation, the liner setting tool is assembled at the surface, as described above, and a glass cloth saturated with a resinous material may be wrapped around the corrugated tube to form the liner. The assembly is lowered into the well at the location at which the liner is to be set. A liquid, such as oil, is then pumped under pressure down the well tubing and flows through the passageway 29 provided in polished rod 31, through ports 32 and into cylinder 33 connected to the upper end of the shoulder 16. Upon the application of fluid pressure to the cylinder, the piston 34 secured to polished rod 31 moves upwardly in cylinder 33. As shown, rod 36 connects polished rod 31 and shaft 18 upon which is mounted the first-stage expanding die 17. When the piston 34 moves upwardly through the cylinder 33 the expanding die 17 and the secondstage die 22 are drawn upwardly into the corrugated liner 14 and "iron out" the corrugations in the liner, so that the expanded liner may contact the inside wall of the casing in which it is being installed. Positioned on the shaft below the expanding member 24 is a constant force spring member 37 which is employed to urge the expanding member against the expanding arms 22 with a substantially constant force. The force exerted against the arm members being substantially constant, the force transmitted through the arm members to the liner and to the casing will be substantially constant so that either sticking of the tool in the casing or rupture of the casing is precluded. Of course, the force provided by the spring member is preselected so that the frictional

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forces between the tool and the liner and the pressure exerted against the casing are maintained at predetermined safe levels. The constant force spring member assures that the contact pressure between the liner forming portion 25 of the arms 22 is great enough to provide the desired deformation of the casing, while preventing damage to the casing or to the tool.

The constant force spring member 37 is slidably mounted on the shaft 18 and held between the expanding element 24 and a cylindrical lower shoulder member 38 forming a portion of a differential screw element 39 which transmits the loading on spring member 37 to shaft member 18. The differential screw element comprises shaft member 18 on the outside of which are cut male threads 18a, the lower shoulder member 38 provided with female threads 38a and thimble member 41 provided with threads 41a and 41b on the outside and the inside, respectively, to engage with threads on the shaft and the shoulder. The two sets of threads are coarse, such as square, modified square, or Acme threads. to withstand very high loads and differ in pitch so that shoulder 38 is moved upwardly on the shaft 18 when the shaft is revolved relative to thimble 41. The shoulder 38 is secured to the shaft 18 by splines 45 so that it can slide longitudinally, but it is not free to rotate on the shaft. Fixedly attached to the lower end of the thimble is a friction member, such as bow springs 42, a hydraulically actuated friction pad, or other such device for frictionally engaging with the inside wall of the conduit to secure the thimble against rotation with respect to the shaft. Preferably, the direction of the shoulder member threads 38a is the same as that of the shaft threads 18a, e.g. righthand threads, and the pitch, or lead, of threads 18a is slightly greater than that of threads 38s, with the pitch ratio being close to unity. In this manner, clock-wise revolution of the shaft relative to the thimble causes shoulder member 38 to advance upward slightly and a compression load is exerted upwardly on spring element 37 to cause buckling. For example, one satisfactory differential screw was made up using five and one-half threads/inch square threads on a shaft approximately 1.7-inch outside diameter and five and threequarters threads/inch square threads on a shoulder approximately 2.5-inches inside diameter.

- 5 -

Constant force spring element 37 comprises column element 43, advantageously consisting of a plurality of elongated columns disposed around shaft 18. Upper bearing plate member 44 is in contact with the upper ends of the columns and is slidably positioned on shaft 18 to transmit the force of the spring longitudinally against the bottom end of expander member 24. Lower bearing plate member 46 contacts the lower ends of the columns and is moved upwardly along the shaft by longitudinal movement of lower shoulder 38 as a result of revolving differential screw element 39. Grooves 47 are provided in each of the bearing plates, to form an upper race and a lower race, into which the ends of the columns are inserted. These grooves may be shaped to conform with the shape of the column ends if desired. A cover 48 may be employed to exclude foreign matter from the spring mechanism and to protect the spring.

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A means for limiting the deflection of the columns is required. Although the column element functions in a buckled condition, application of excessive compressive load thereto would cause total failure or rupture of the columns. Therefore, a pair of stops 49 and 49a are provided for this purpose. As shown, the stops are rigidly connected to the bearing plates, and, in effect comprise upper and lower limiting sleeves positioned on the shaft to slide longitudinally thereon. The ends of the stops may move toward, or away from, each other as the load on the spring member varies. Lower sleeve 49a is prevented from moving down by lower shoulder 38 connected to the shaft 18. However, the spacing between the ends is such as to limit the longitudinal travel of the bearing plate members as they move together to prevent permanent deformation of the column element 43. Various alternative means for preventing damage to the column element may also be employed. For example, pins or rings mounted on the shaft may serve as stops, or the cover 48 provided with suitable connections may be employed for this purpose to limit longitudinal and/or lateral deflection of columns.

The columns of the column element 43 may be arranged around the shaft 18, which as shown here forms a portion of the body of the spring device, with ends of the columns fitted in the races 47. The columns may be

fitted closely together as shown, or may be spaced around the race, with separators used between them to maintain the desired spacing. The number of columns employed will depend upon column characteristics and the materials of construction. For exemple, the slenderness ratio of the column may be varied widely, and the column ends may be round, flat, fixed or hinged. The preferred construction is a thin, slender column with rounded ends, free to move within the races shaped to the curvature of the column ends. Materials which may be satisfactorily employed for the columns are carbon and low alloy steels, chromium and nickel-chromium stainless steels, various copper base alloys, such as phosphor bronze, beryllium copper, the high nickel alloys and other similar materials providing satisfactory mechanical properties. Typically, the individual columns are of long rectangular cross-section, with the width being greater than the thickness, and arranged so that the wider face of the columns is normal to the diameter of the shaft. Thus, with sufficient compression loading, the columns buckle, and bend about the axis having the least moment of inertia, e.g., outwardly away from the shaft 18.

For example, a group of columns 0.167-inch thick by 0.438-inch wide by 10.626-inches long, with the ends rounded, were fabricated from A.I.S.I 4340 steel, quenched and drawn at 575°F. Each column was found to require a 20 critical compression loading of 450 pounds in order to buckle the column. After buckling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, wherein $P_{\rm c}$ is the critical buckling load and point C represents the load and deflection at which the stress in the extreme fibers of the column exceed the yield point of the material. Theoretically, the shape of this spring characteristic curve is described by curve OA'ABC. Actually, this curve is described by OABC due to friction in the system. Points A and B represent typical working limits, which, of course, may be varied according to the application for which the spring is designed. For example, where a large number of flexing cycles are not anticipated, a working stress just below the 30 yield point may be used, while with a great number of flexures, the working stress may be held to less than the endurance limit of the material of construction. In the above-mentioned tests, the lateral deflection was limited to

spproximately one inch, at which the longitudinal deflection was approximately: 0.225 inches. From zero deflection to the maximum deflection, the 450-pound loading was found to be substantially constant.

In another test a spring device was built, as shown, employing 20 columns, each having a critical buckling load of 1250 pounds. The lateral deflection was limited between 0 and about 1.00 inches by appropriately positioning the stops. Upon compressional loading, the spring element buckled at substantially 25,000 pounds and from a longitudinal deflection of 0.04 inches (buckling) to about 0.15 inches the load remained substantially at 25,000 pounds.

Of course, in designing a spring element as above it is advantageous to obtain the greatest possible value of longitudinal deflection for specified values of lateral deflection and critical buckling load, while maintaining the stress level in the columns at a safe level. The preferred columns, therefore, are laminated, as shown in Figures 1B and 2, with multiple flat members making up each column.

In the operation of the above expanding tool for setting a liner in well casing, the made-up tool is lowered into the well as mentioned above, with the arms 22 in the retracted position. When the tool is at the desired level, the well tubing is revolved. The friction member 42 engages with the wall of the casing and prevents thimble 41 from revolving. With several revolutions of the tubing, lower shoulder 38 is moved upwardly by differential screw 39 to buckle spring element 37 which has a predetermined critical buckling load. This load is transmitted upwardly against the lower end of expander 24, and its tapered surface is engaged with the tapered surface on the inside of the arms 22 to urge the arms outwardly with a substantially constant force proportional to the critical buckling load of the spring element. Subsequently, the expanding tool is passed through the liner to expand it in the casing in the manner described hereinbefore.

The foregoing description of a preferred embodiment of my invention has been given for the purpose of exemplification. It will be understood that various modifications in the details of construction will become apparent to

the artisan from the description, and, as such, these fall within the spirit and scope of my invention.

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I CLAIM:

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- 1. A device for expanding a metallic liner inside a conduit which 1 device comprises a shaft element, an expanding die member attached to said 2 shaft element, said die member comprising a movable liner-forming member positioned on said shaft and being radially movable in respect thereof to contact said liner, an expander member slidably positioned on said shaft 6 between said shaft and said die member to move said liner-forming member from said shaft, and a constant force spring member positioned on said shaft 8 to contact said expander member and to maintain said expander member against said liner-forming member, whereby said liner-forming member is urged against 9 10 said liner by a substantially constant force.
- 2. In a device for installing an expanded metallic liner in a 1 2 conduit wherein an expanding die is moved through a liner positioned in said conduit to expand said liner: a cylindrical shaft element, an expanding die 3 member attached to said shaft, said die member comprising a plurality of arm 4 5 members disposed around said shaft and being pivotable outwardly therefrom to 6 contact said liner, a cone member slidably positioned on said shaft between 7 said shaft and said arm members to urge said arm members outwardly from said 8 shaft, and a constant force spring member positioned on said shaft to contact 9 said cone member and to maintain said cone member in contact with said arm 10 members, whereby said arm members are urged outwardly by a substantially n constant force.
 - 3. The device of Claim 2 wherein said constant force spring member comprises a plurality of columns disposed around said shaft, a first bearing plate member and a second bearing plate member, each of said bearing plate members contacting opposite ends of said columns, at least one of said bearing plate members being movably positioned on said shaft and being in contact with said come member, stop means connected to said shaft to limit the axial travel of said movable bearing plate member along said shaft, and compression means for maintaining a lateral deflection in said columns.

- 1 4. The device of Claim 3 wherein said compression means comprises
 2 a differential screw connecting said spring member and said shaft.
- 5. The device of Claim 3 wherein said stop means comprises a

 2 sleeve-like element connected to said movable bearing plate member and

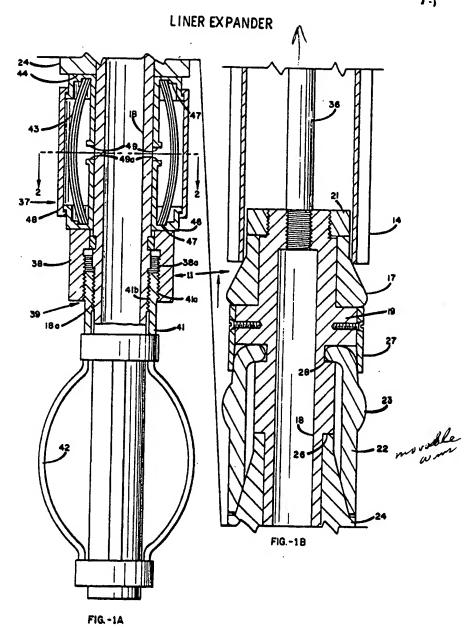
 3 slidably positioned on said shaft and a member connected to said shaft to

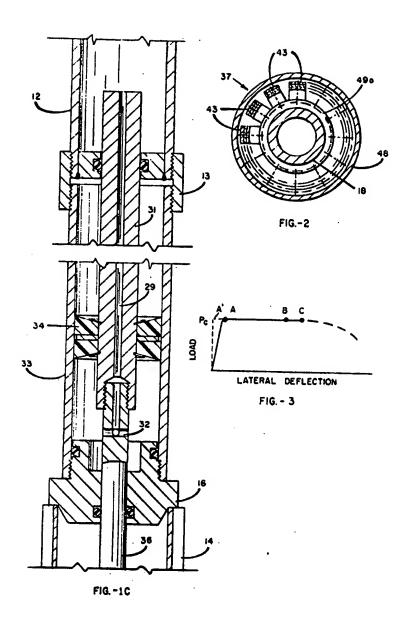
 4 limit the travel of said sleeve-like element.
- 6. The device of Claim 3 wherein said columns have a rectangular cross-section, the width being greater than the thickness, and having the wider face normal to the diameter of said chaft.
- 1 7. A device for installing an expanded metallic liner in a conduit which comprises a cylindrical shaft element; an expanding die member mounted 2 on said shaft, said die member comprising a plurality of arm members disposed circumferentially around the outside of said shaft and being pivotable outwardly therefrom to contact the liner; a conical expanding member slidably positioned on said shaft between said shaft and said arm members to urge said 6 arm members outwardly from said shaft; a plurality of slender columns, each 7 8 having a long rectangular cross-section and disposed circumferentially about said shaft; an upper bearing plate member and a lower bearing plate member, 9 each slidably positioned on said shaft and contacting opposite ends of said 10 columns; limiting sleeves attached to each of said bearing plate members \mathbf{n} and slidably positioned on said shaft; a shoulder member on said shaft; a 12 differential screw element connecting said shoulder and said shaft to apply 13 a buckling load to said columns; said shoulder being engageable with the 14 limiting sleeve connected to said lower bearing plate member, whereby the 15 axial travel of said bearing plate members is limited; said column members 16 transmitting their buckling load to said arm members to urge said arm members 17 18 outwardly with a substantially constant force.

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In A device for expending a metallic line; touche a conduct which device comprises a shaft almost, an aspecting the master attended to said shaft closest, which dis member comprising a movable liner-forming member positioned on said shaft and being catially moveble in respect thereof to contact said liner, as expender moves alidably positioned on said shaft between said shaft and said dis number to move said liner-forming member from said shaft, and a constant force spicing number scattered on said staff, and a constant force spicing number scattered on said staff, and a constant force spicing number scattered on said staff, and a constant three spicing number scattered on said staff, and a constant force spicing number is urged against said liner-forming number, whereby said liner-forming number is urged against said liner by a mbettastially constant force.

2. In a device for installing an expended schalic liner in a conduct wherein an expending size is moved through a liner positional in said stockets to expend said liner: a cylindrical start alment, an expending size season to expend said shaft, said dis newbor commissing a pissality of any masters discussed around said shaft and being pivotable extensity therefore to contact still liner, a come member shishiby qualificated on said shaft between said shaft and mainters to very said are members colonately from said shaft, and a constant force spring number positioned on said shaft to contact still come member in somice with said are members, whereby said one members outpartly by a substantially constant force,

3. But device of Claim 2 shareds, said sometant from spring number comprises a plannisty of columns disposed sected each shaft, a first bearing plate somer and a second bearing plate somer, each of said bearing plate suchers contacting opposite cale of said columns, at least one of said bearing plate numbers being speakly positioned on said shaft and being in contact with said some member, step somer commerted to said start to limit the axial traval of said somethle bearing plate number along said shaft, and compression means for waintaining a lineral dericettien in said columns.





- . A. the device of Claim 3 whereis entit compression grams comprises a differential survey connecting mile agring number and smill shaft.
- 5. The divides of Chain 3 wherein sold stop means comprises a alcove-like element accessed to said wowhle bearing plate assure and stillning positioned on said shaft and a scaled companied to eate shaft to limit the transit of said alcove-like element.
- 6. The device of their 3 wherein soil column have a rectangular cross-stocken, the width being greater than the flickness, and basing the sider flow sevent to the dissertor of said shaft.
- vice for installing at expended ustallis liner in a conduct defense a cylindrical shafe classics on argenting dis sucher mounted on mid shaft, said the senter comprising a plantity of are senters disposed formulally around the outside of said shaft and buing pluotable outearly meretres to contest the liner; & statest expending maker slifely nontthough on said shart between said shaft and said are explored to tops said w outwardly from said shaft; a planelity of aleader columns, each ngular cross-section and disposed eirestferentially shout suid chaft; an upper bearing plate sender and a lower bearing plate seator, such slikely positioned on said shaft and outseting opposite and of said column; limiting alserse utriaded to each of said bearing plate numbers and alidably positioned on said statts a shoulder masket on such shafts a differential some classes connecting said shoulder and said short to apply a backling load to only columns; said thoulder being comparable with the limiting cleave memoried to entil looky bearing plate memory, werety the branesitting their buckling load to eald arm numbers to urgs said arm spec extendily with a substantially constant force.





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form, a satisfic and apparetne have been developed for or region added no files in an at their partition belonger on the Typically, a correspind attack lines is imported in a contrib which he in be the greatest pariphosis. Simesion of the liner being eligibly less es plantic deformation of the liner, which is agranied outwardly provides an abilitiesal firms deformation of the limes to provide a smoother, ares finished surface on the incide of the lines and to weeker some on contact between the compute and the liner. In a typical design of this type ng tool, the frictional drug of the first-stage die supplies the expending rares for the second-stage die, which expending force is a street function of the strength, or wall thickness, of the conduit in which the limer is being installed. For example, in liming all well custom, heavy se a very high triniform! force which results in excessive me bring required to yosh the expender through the liner. The aring of the greet forces required may result in ruphure of the casing uring the installing tool. In tastemee where the interval. mhat less then that artistated, the results age to the eneing and the tool. In other dualgra, such as the nt spring arrangment in employed in economistan with the secondstign die, verloos difficulties are encountered in obtaining a spring ion beving the desired strength is continution with the other spring. existion, and with the took dragging against the itselfs will of the module after being passed through the liner.

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In accordance with the present invention there is provided a convisit force spring device which comprises a body member, an elospated solumn element adjacents said body number, bearing plate numbers contenting the two world of anid column at least one of said bearing plate numbers being langicutinally neverty in respect of the other and stop seems on said body whether to limit the definition of said solumn element to prevent parametriz defermedting of said solumn element upon the application of a compressive load thereto. In our actelizant of the investion, the foregoing constant torsespring device is explayed in a tool for expending a satallic liner invide a content, said constant force spring device being partitioned on each tool to ways an expending the number agency the liner being installed in the conduct ty a substantially constant force.

By invention will be better understood by reference to the following description and the accompanying drawings wherein:

Figure 1A, 13 and 1C, taken together, constitute a portial sectional rise of a preferred embediament of a liner expending tool assembling to the present investion; and

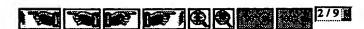


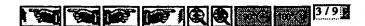


Figure 2 to a sectional view of the apparatus of Figure 1A taken at

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Figure 3 is a typical plot of applied load versus Deflection for the complete force spring device of the Leventice.

Referring to the arcrings, Figure 15 is the bottom portion of a liner expensing tool for one in installing a motalile liner in a well, while Figure 13 Libertrotes the statte section of such a tool and Figure 10 represeats the upper sertion of the tool. The expending tool 11 is attended to stantant real toking 18 by compling 15 and, typically, may be inverse from the th dains in paints of a large a of (moute ton) gaines fire a dan to desired to install a metallic liner. Defore inserting the test into the well, as alcounted vertically corrected liner in Cabricated Cross still steel, or pultable enthable pertorial, is placed on the tool. The corregated liner is occured in position by contact at its upper end with a cylindrical shoulder marker 16 and, at the lover and by contact with a first-stage expanding die 17 in the form of a trumested circular some shick serves as a firstading die in the second bereinefter described. The expending die La d to a centrally located, elemented epidetrical bollow shaft lô is held in place between a lower abouther 19 and collar 21 threaded outo the chart. . A plurality of morphic arms 25, preservably provided with outwardly cularged portions 25 sear the top; are disposed in the form of a splinder around that's 18. The enlarged purbloss of the sens 23 upon being moved outverily emissed the liner to purfoce the final step of expending the sucregated liner into a substantially syllatrical shape. The are conhere EE are pivotally d to the sheft so as to be moveble outsavely from the sheft by a tapered expending newber 26 aliably positioned on the short to serve as a second-stage expender. The surface of the mester 2h, as shown, moves upwardly along the start to angus with the arms and move them outwardly. Advantageously, the inside surfaces of the erms 22 and the outside surface of expending smaller 24 form meting sentions, typically categoral is shape. The expension of the arm to is controlled by the position of the member 24 which moves appearely



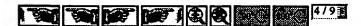


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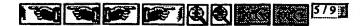
writh it contents shoulder 25 provided on two sheft. As number 25 worse in a documently direction area 22 feld invertily towark the sheft. The expending area 22 are held to place on the sheft by colles 27 and circular groom 26 resulted on the sheft.

The expending tool, comprising the first-stage die and the secondstage die is dress through the limit to expend it in place in the casing. Die first-stage die provides a gross deformation of the liner so that it is expended outwardly against the wall of the sening. The second-stage die then peases through the liner and perform the final expenden to smooth the inner surface of the liner and to provide more even content between the liner and the wall of the casing and effect a finid-tight seal.

In operation, the liner setting tool is secondled at the surface, so described shore, and a glass cloth seturated with a restauce material my be the corregated take to form the liner. The assembly is lowered so oil, in them pusped under presence down the well tubing and flows through gency 29 provided in polished rol 31, through parts 52 and into equinder 35 consisted to the upper and of the shoulder 16. Upon the application of first pressure to the cylinder, the pistes 34 second to polished rol 31 moves operatly in syltader 33. As shows, rot 36 consects polished rot 31 and shaft ourted the riret-stage expeeding die 17. When the piston 34 moves upwordly through the cylinder 33 the expanding die 17 and the secondstage die 22 are draws upwardly into the corrupted liner 18 and "iron out" the corregations in the liner, so that the expected liner may contact the incide wall of the casing in which it is being installed. Poritiosof on the substantially sometant force. The force exacted against the arm sembles being substantially constant, the force transmitted through the arm numbers to the of the tool in the centag or regions of the curing is precluded. Of so the Strong provided by the spring number to preselected so that the frictional



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Zerose between the tool and the liner and the presence emerted against the oneing are emircaled at predeterateed eafo levels. The constant terms spring makes assures that the contact presence between the liner founding portion 25 of the open 22 is great ecough to provide the desired deformation of the obstion, while recognition demons to the easing at to the tool.

The operators forces spring sender 37 is alighbly monited on the shaft 18 and half between the expending alsoque \$6 and a cylindrical lower shoulded master 35 forcing a portion of a differential screw alsows 39 which terments has looking on spring member 37 to mark member 18. The differential convertables of shigh are out sold threads 18a, the lower shoulder master 35 provided with female threads 55s and thinkle member 18, provided with threads of the incide, respectively, to sepage with threads and file us about and the shoulder. The two code of threads are souths, such as square, modified square, or done threads, to withstand very high loads and differ in pitch so that monther 35 is several specify on the shaft 18 when the shaft 1s revolved relative to thinkle \$1. The choolier 35 is secured to the shaft 18 by splines \$5 so that 21 can alide longitudically, but it is not tree to rotate on the shaft. Finally attached to the lower and of the thinkle is a friction scalar, such as but aprings \$2, a apticularly estuated friction past, or other such sevine for frietionally magazing with the isolds wall of the amplit to occure the thinkle against toolscan with respect to the shaft. Preferably, the direction of the doublier master threads 35s, with the pitch rotate of the shaft threads 18s, e.g. righthand threads 35s, with the pitch rotate bring alove to unity. In this same, clock-wise revolution of the shaft relative to the thinkle senses thoulder assets 55 to advance square alightly and a congression load is americal square threads on a shaft approximately 1.7-inch outside dissector and five and threads threads on a shaft approximately 1.7-inch outside dissector and five and threads and threads approximately 1.7-inch outside dissector and five and threads.





Donatent force spring element 37 comprises unline element b3, etwatageomaly committing of a plurality of alongsted column disposed around short

15. Upper bearing place content the in contact with the apper ends of the
columns and is although positionois to shart if to trespect the force of the
spring langitudinally against the bottom and of expendes sendor 56. Lover
bearing place number 66 contacts the lower ands of the columns and 12 noved
specially along the start by lengthesiani novement of lower shoulder 55 on a
result of revaliding differential survey almost 39. Grooves 57 are provided
in such or the bearing places, to form an upper race and a lover case, into
which the costs of the column are inserted. These grooves may be chaped to
contern with the shape of the column such if seatred. A cover 55 may be
employed to another forwige author from the spring mechanism and to protect
the corrier.

A name for limiting the deflection of the columns to required.

Although the column element functions in a bushled condition, application of excessive acquires the load thereto would sense total failure or reptere of the solumn. Therefore, a pair of stops to sand the are provided for this purpose. As shown, the stops are rigidly commerced to the bearing plaine, and, in effect comprise upper and lower limiting slaseres positioned on the short to alide longitudinally thereon. The unit of the stops my some toward, or sany from each other so the load in the spring number vertex. Lower slaves by in prevented from moving dams by loader shoulder 58 accumented to the eart 18. However, the spacing between the sode in much as to limit the longitudinal liveral of the bearing plats manhers as they more together to prevent permanent deformation of the column alament 55. Tarious alternative manus for preventing slanage to the column alament to be employed. For example, plus or rings seement on this chart may serve as atops, or the cover 48 provides with estimative interval seriestion of columns.

The columns of the column classest \$5 may be arranged eround the coast 16, which as shown here forces a portion of the body of the spring device, with made of the column fitted in the recen \$7. The column my be

and the second programmer and the second pro

6/9

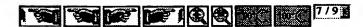


ritted closely together as shown, or very an spared around the race, with separators used between them to meintain the desired spacing. The runbal of columns amplicated will depend upon column observatation and the materials of constraintion. For example, the elements ratio of the column may be waited widnly, see the column only not be recent, flat, fixed or hinged. The preferred completely is a thin, a) under column with touried ends, free to nove within the races shaped to the convenience of the column ands. Materials which may be satisfactorily employed for the addisms are carbon and ice alloy steels, chrowing and michal-shrowing stables stools, various appear been allies, such as passaged transco, beryllins support, the high michal alloys and other minitar attends providing antisfactory weakenismi properties. Typically, the individual column are of long rethempolar cross-cention, with the midth bring greater than the thickness, and arranged so that the wider race of the solumns is somether to the attends of the shart. Thus, with surfacient properation loading, the columns backle, and hand shout the said having the loast comput of inertia, e.g., columnity may from the shart 15.

For example, a group of column 0.167-inch thick by 0.438-inch wisc by 10.626-inchew long, with the ands rounded, were fabricated from i.f.S.I 4360 wheel, questabed and draws at 575°F. Bush column was found to require a critical sumpression loading of 550 pounds in order to bunkle the address.

After bunkling, the columns were found to have a very flat spring characteristic, as shown in Figure 3, theretis P₀ is the critical bunkling load and point 0 represents the load and deflection at which the circus in the external flat of the substance fibers of this spring characteristic curve is described by stave Od'ABO. Actually, this curve is described by carve Od'ABO. Actually, this curve is described by CABO due to friction in the system. Fortest A and I represent typical working limits, which, of course, may be warfed according to the application for which the spring is designed. For example, where a large masher of flaxing system are not ambicinated, a working atrees just below the vices may be held to have than the endurance limit of the seterial of construction. In the above-maritional basis, the internal defaction was limited to

- 7 -





approximately one inch, at which the longitudinal deflection was approximately 0.225 inches. From more defination to the assume deflection, the \$50-pound loading was found to be substantially constant.

In emother test a spring device was built, so down, employing 20 column, each having a critical buckling load of 1250 years. The internal definition was limited between 0 and about 3.00 inches by empropriately positioning the stops. Such compressional loading, the spring element buckled at constantially 25,000 pounds and from a longitudinal deficacion of 0.00 inches (bushling) to stook 0.15 inches the load remained substantially at 27,000 pounds.

Of course, in doriging a spring elevant as above it in advantagements obtain the greatest possible value of longitudinal definations for specified unions of laboral deflection and critical bushing load, while universing the atmost level in the columns at a cafe level. He preferred columns, therefore, are laminated, as shown in Figures 12 and 2, with multiple flat members uniter to each column.

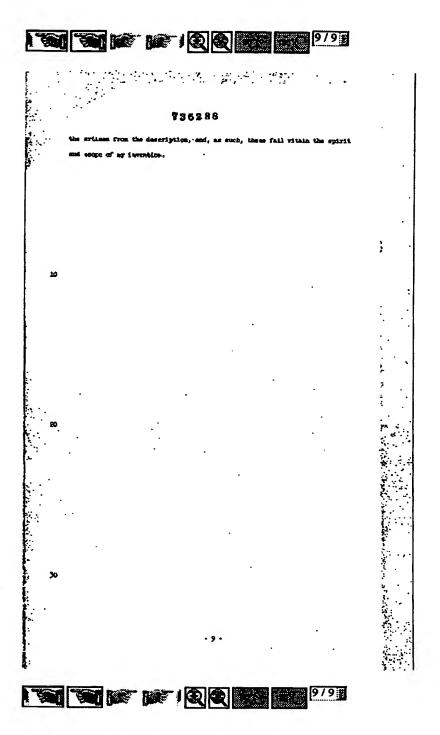
In the operation of the shows expecting tool for setting a liner in well emerge, the under-up tool is lowered late the well as mestioned above, with the area 22 in the retreated position. Then the tool is at the desired level, the sell tubing is revelved. The fristion number of traggers with the wall of the seeing and prevents thinkin 41 from revolving. With several revolutions of the tubing, lower shoulder 36 is moved meantly by differential server 39 to bush a spring allowest 37 thick has a predeterminal critical buckling load. This lead is transmitted specially against the lower and of expender 36, and the tapered surface is engaged with the tapered surface on the incide of the orne 22 to argu the turn cutturally with a substantially constant force proportional to the critical buckling load of the spring almost. Subsequently, the expending tool is passed through the liner to expend it in the caping in the secons described breakedore.

the foregring description of a preferred embedient of ay investigahas been given for the purpose of complification. It will be understood that various medifications in the descript of accordance will become appearant to

- 8 -

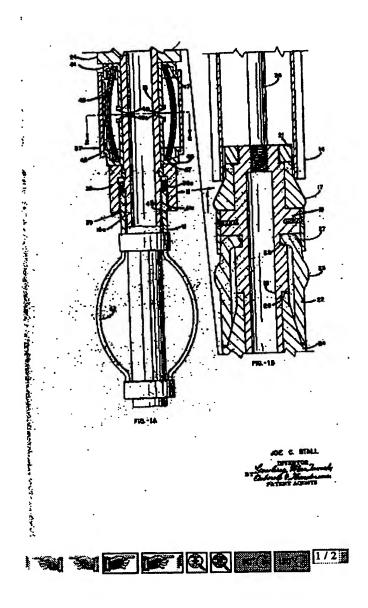
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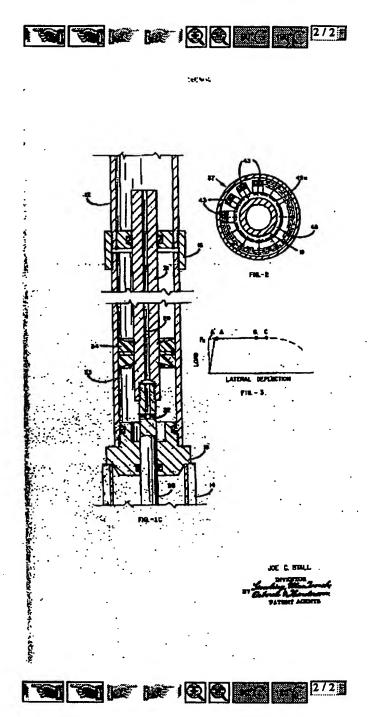






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